

CLAIMS

We Claim:

1. A method for improving the performance of a device having a movable microstructure that comprises an element that plastically deforms and operates in a first deformed state and a second state, the method comprising:
repeatedly actuating the element to the first deformed state; or holding the element at the first deformed state for a particular time period so as to cause the element to acquire an amount of plastic deformation that is at least 1.5% of a predetermined maximum plastic deformation that can be developed during the operation of the element; and
delivering the device to a customer.
2. The method of claim 1, wherein the predetermined maximum plastic deformation is an amount of plastic deformation developed after at least 10,000 hours of operation of the element.
3. The method of claim 1, wherein the predetermined maximum plastic deformation is equivalent to a droop angle for the element of 0.8° degrees or more.
4. The method of claim 1, wherein the step of repeatedly actuating the element further comprises:
repeatedly actuating the element to the first deformed state in response to a series of signals each of which corresponds to an ON state so as to achieve a maximized brightness.
5. The method of claim 1, wherein the customer is a retail customer and the microstructure is a micromirror within a spatial light modulator of a projection system.
6. The method of claim 2, wherein customer is a projection system manufacture.
7. The method of claim 1, wherein the element comprises TiAl_x .
8. The method of claim 1, wherein the element comprises SiNi_x .

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9. The method of claim 1, wherein the element comprises an early transition metal nitride.
10. The method of claim 1, wherein the step of repeatedly actuating the element further comprising:
repeatedly actuating the element that is a hinge of a micromirror device, the hinge having a mirror plate attached thereto such that the mirror plate is operable to rotate.
11. The method of claim 1, wherein the step of holding the element at the deformed state for the particular time period further comprises:
holding the element at the deformed state for a particular time period of from 5 minutes to 500 hours.
12. The method of claim 1, wherein the step of holding the element at the deformed state for the particular time period further comprises:
holding the element at the deformed state for a particular time period of from 20 minutes to 24 hours.
13. The method of claim 5, further comprising:
heating the microstructure to a temperature of from 20 °C to 120 °C degrees during the step of repeatedly actuating the element or holding the element at the first deformed state.
14. The method of claim 5, further comprising:
heating the microstructure to a temperature of from 120 °C to 200 °C degrees during the step of repeatedly actuating the element or holding the element at the first deformed state.
15. The method of claim 5, further comprising:
heating the microstructure to a temperature of from 200 °C to 500 °C degrees.
16. The method of claim 1, further comprising:
obtaining a development of plastic deformation in the element over time; and

determining the particular time period according to the obtained development of the plastic deformation.

17. The method of claim 7, wherein the step of determining the particular time period further comprises:

determining an initial amount of the plastic deformation that is developed during a first time period and is at least 1% of the maximum plastic deformation that can be developed by the deformable element; and

determining the particular time period for holding the element at the deformed state according to the first time period such that after holding the element for the particular time period, the acquired deformation encompasses the initial amount of the plastic deformation.

18. The method of claim 8, wherein the initial amount of the plastic deformation is at least 3% or more of the maximum plastic deformation.

19. The method of claim 8, wherein the initial amount of the plastic deformation is at least 5% or more of the maximum plastic deformation.

20. The method of claim 8, wherein the initial amount of the plastic deformation is at least 60% or more of the maximum plastic deformation.

21. The method of claim 1, further comprising:
packaging the microstructure before performing the steps of deforming the element.

22. The method of claim 1, further comprising:
packaging the microstructure after the steps of defining the new non-deformed state.

23. The method of claim 1, wherein the step of deforming the element to the deformed state further comprises:

rotating a mirror plate that is attached to the deformable element to an ON state angle on a substrate, wherein the ON state angle is from 10° to 18° degrees between the mirror plate and the substrate.

24. The method of claim 1, wherein the deformable element comprises a material that is an elemental metal, metalloid, metallic compound or ceramic.

25. The method of claim 1, wherein the deformable element comprises a material that is polycrystalline, amorphous or nanocrystalline.

26. A method for improving the performance of a device having a movable microstructure that comprises an element that plastically deforms and operates in a first deformed state and a second state, the method comprising:

predetermining an amount of desired plastic deformation of the element at a non-actuated state;

repeatedly actuating the element to a first deformed state; or holding the element at the first deformed state for a particular time period so as to cause the element to acquire the desired amount of plastic deformation at the non-actuated state; and

delivering the device to a customer.

27. The method of claim 26, wherein the step of repeatedly actuating the element further comprises:

repeatedly actuating the element to the first deformed state in response to a series of signals each of which corresponds to an ON state so as to achieve a maximized brightness.

28. The method of claim 26, wherein the customer is a retail customer.

29. The method of claim 26, wherein the step of repeatedly actuating the element further comprising:

repeatedly actuating the element that is a hinge of a micromirror device, the hinge having a mirror plate attached thereto such that the mirror plate is operable to rotate.

30. The method of claim 26, wherein the step of holding the element at the deformed state for the particular time period further comprises:

holding the element at the deformed state for a particular time period of from 5 minutes to 500 hours.

31. The method of claim 26, wherein the step of holding the element at the deformed state for the particular time period further comprises:

holding the element at the deformed state for a particular time period of from 20 minutes to 24 hours.

32. The method of claim 30, further comprising:

heating the microstructure to a temperature of from 20 °C to 120 °C degrees during the step of repeatedly actuating the element or holding the element at the first deformed state.

33. The method of claim 30, further comprising:

heating the microstructure to a temperature of from 120 °C to 200 °C degrees during the step of repeatedly actuating the element or holding the element at the first deformed state.

34. The method of claim 30, further comprising:

heating the microstructure to a temperature of from 200 °C to 500 °C degrees during the step of repeatedly actuating the element or holding the element at the first deformed state.

35. The method of claim 26, further comprising:

obtaining a development of plastic deformation in the element over time; and
determining the particular time period according to the obtained development of the plastic deformation.

36. The method of claim 32, wherein the step of determining the particular time period further comprises:

determining an initial amount of the plastic deformation that is developed during a first time period and is at least 1% of the maximum plastic deformation that can be developed by the deformable element; and

determining the particular time period for holding the element at the deformed state according to the first time period such that after holding the element for the particular time period, the acquired deformation encompasses the initial amount of the plastic deformation.

37. The method of claim 32, wherein the step of determining the pattern further comprises:

determining an initial amount of the plastic deformation that is developed during a first time period and is at least 1.5% or more of the maximum plastic deformation;

38. The method of claim 33, wherein the initial amount of the plastic deformation is at least 3% or more of the maximum plastic deformation.

39. The method of claim 33, wherein the initial amount of the plastic deformation is at least 5% or more of the maximum plastic deformation.

40. The method of claim 33, wherein the initial amount of the plastic deformation is at least 60% or more of the maximum plastic deformation.

41. The method of claim 26, further comprising:
packaging the microstructure before performing the steps of deforming the element.

42. The method of claim 26, further comprising:
packaging the microstructure after the steps of defining the new non-deformed state.

43. The method of claim 26, wherein the step of deforming the element to the deformed state further comprises:

rotating a mirror plate that is attached to the deformable element to an ON state angle on a substrate, wherein the ON state angle is from 10° to 18° degrees between the mirror plate and the substrate.

44. The method of claim 26, wherein the deformable element comprises a material that is an elemental metal, metalloid, metallic compound, or ceramic.

45. The method of claim 26, wherein the deformable element comprises a material that is polycrystalline, amorphous or nanocrystalline.

46. A method for improving the performance of a device having a movable microstructure that comprises an element that plastically deforms and operates in a first deformed state and a second state, the method comprising:

acquiring an amount of plastic deformation, comprising:

repeatedly actuating the element to the first deformed state; or holding the element at the first deformed state for a time period of 1 hour or more so as to cause the element to acquire an amount of plastic deformation; and

shipping the device to a customer.

47. The method of claim 46, wherein the step of acquiring the amount of plastic deformation further comprises:

holding the element at the first deformed state for a time period of 10 hours or more.

48. The method of claim 46, wherein the step of acquiring the amount of plastic deformation further comprises:

holding the element at the first deformed state for a time period of 50 hours or more.

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50. The method of claim 46, wherein the step of acquiring the amount of plastic deformation further comprises:

holding the element at the first deformed state for a time period of 100 hours or more.

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51. The method of claim 46, wherein the step of repeatedly actuating the element further comprises:

repeatedly actuating the element to the first deformed state in response to a series of signals each of which corresponds to an ON state so as to achieve a maximized brightness.

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52. The method of claim 46, further comprising:
obtaining a development of plastic deformation in the element over time; and

determining the particular time period according to the obtained development of the plastic deformation.

52/53. The method of claim 48, wherein the step of determining the particular time period further comprises:

determining an initial amount of the plastic deformation that is developed during a first time period and is at least 1% of the maximum plastic deformation that can be developed by the deformable element; and

determining the particular time period for holding the element at the deformed state according to the first time period such that after holding the element for the particular time period, the acquired deformation encompasses the initial amount of the plastic deformation.

53/54. The method of claim 49, wherein the initial amount of the plastic deformation is at least 3% or more of the maximum plastic deformation.

54/55. The method of claim 49, wherein the initial amount of the plastic deformation is at least 5% or more of the maximum plastic deformation.

55/56. The method of claim 49, wherein the initial amount of the plastic deformation is at least 60% or more of the maximum plastic deformation.

56/57. The method of claim 47, wherein the step of deforming the element to the deformed state further comprises:
rotating a mirror plate that is attached to the deformable element to an ON state angle on a substrate, wherein the ON state angle is from 10° to 18° degrees between the mirror plate and the substrate.

57/58. The method of claim 47, wherein the particular time period is from 5 minutes to 800 hours.

58/59. The method of claim 44, wherein the particular time period is from 1 to 24 hours.

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60. The method of claim 45, further comprising: raising the temperature of the microstructure to a value of from 20° to 120 °C during the step of repeatedly actuating the element or holding the element at the first deformed state.

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61. The method of claim 45, further comprising: raising the temperature of the microstructure to a value of from 120° to 200 °C during the step of repeatedly actuating the element or holding the element at the first deformed state.

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62. The method of claim 45, further comprising: raising the temperature of the microstructure to a value of from 200° to 500 °C during the step of repeatedly actuating the element or holding the element at the first deformed state.

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63. The method of claim 46, wherein the deformable element comprises a material that is an elemental metal, metalloid, metallic compound or ceramic.

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64. The method of claim 46, wherein the deformable element comprises a material that is polycrystalline, amorphous or nanocrystalline.

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65. The method of claim 46, further comprising:
packaging the microstructure before performing the steps of acquiring the amount of plastic deformation.

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66. The method of claim 46, further comprising:
packaging the microstructure after the steps of acquiring the amount of plastic deformation.

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67. A method of improving the lifetime of a spatial light modulator having an array of micromirrors, wherein the micromirror has a reflective mirror plate attached to a hinge such that the mirror plate can rotate between an ON and OFF state, the method comprising:
acquiring an amount of plastic deformation for the deformable element;
defining a new OFF state according to the original OFF state and the acquired plastic deformation; and

operating the microstructure at the new OFF state and the ON state.

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68. The method of claim ⁶⁶67, wherein the step of acquiring the amount of plastic deformation further comprises:

setting the mirror plates to a deformed state; and

holding the mirror plates at the deformed state for a particular time period.

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68. The method of claim ⁶⁶67, further comprising:
calibrating the microstructure based on the third state such that the microstructure can be operated in the first deformed state and the third state.

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69. The method of claim ⁶⁷68, wherein the step of holding the element at the deformed state for the particular time period further comprises:
holding the element at the deformed state for a particular time period of from 5 minutes to 500 hours.

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70. The method of claim ⁶⁷68, wherein the step of holding the element at the deformed state for the particular time period further comprises:
holding the element at the deformed state for a particular time period of from 20 minutes to 24 hours.

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71. The method of claim ⁶⁷68, further comprising:
heating the microstructure to a temperature of from 20 °C to 120 °C degrees during the step of repeatedly actuating the element or holding the element at the first deformed state.

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72. The method of claim ⁶⁷68, further comprising:
heating the microstructure to a temperature of from 120 °C to 200 °C degrees during the step of repeatedly actuating the element or holding the element at the first deformed state.

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73. The method of claim ⁶⁷68, further comprising:
heating the microstructure to a temperature of from 200 °C to 500 °C degrees during the step of repeatedly actuating the element or holding the element at the first deformed state.

~~73~~⁷³. The method of claim 67, further comprising:
 obtaining a development of plastic deformation in the element over time; and
 determining the particular time period according to the obtained development of the plastic deformation.

~~74~~⁷³~~76~~. The method of claim ~~76~~⁷³, wherein the step of determining the particular time period further comprises:
 determining an initial amount of the plastic deformation that is developed during a first time period and is at least 1% of the developed maximum plastic deformation; and
 determining the particular time period for holding the element at the deformed state according to the first time period such that after holding the element for the particular time period, the acquired deformation encompasses the initial amount of the plastic deformation.

~~75~~⁷⁴~~77~~. The method of claim ~~77~~⁷⁴, wherein the initial amount of the plastic deformation is at least 1.5% or more of the maximum plastic deformation;

~~76~~⁷⁵~~78~~. The method of claim ~~78~~⁷⁵, wherein the initial amount of the plastic deformation is at least 3% or more of the maximum plastic deformation.

~~77~~⁷⁶~~79~~. The method of claim ~~79~~⁷⁶, wherein the initial amount of the plastic deformation is at least 5% or more of the maximum plastic deformation.

~~78~~⁷⁷~~80~~. The method of claim ~~80~~⁷⁷, wherein the initial amount of the plastic deformation is at least 60% or more of the maximum plastic deformation.

~~79~~⁶⁶~~81~~. The method of claim ~~81~~⁶⁶, further comprising:
 packaging the microstructure before performing the steps of acquiring the amount of plastic deformation.

~~80~~⁶⁶~~82~~. The method of claim ~~82~~⁶⁶, further comprising:

packaging the microstructure after the steps of acquiring the amount of plastic deformation.

81/83. The method of claim ~~68~~⁶⁷, wherein the step of setting the mirror plate to the deformed state further comprises:

rotating a mirror plate that is attached to the deformable element to an ON state angle on a substrate, wherein the ON state angle is from 10° to 18° degrees between the mirror plate and the substrate.

82/84. The method of claim ~~67~~⁶⁶, wherein the deformable element comprises a material that is an elemental metal, metalloid, metallic compound or ceramic.

83/86. The method of claim ~~67~~⁶⁶, wherein the deformable element comprises a material that is polycrystalline, amorphous or nanocrystalline.